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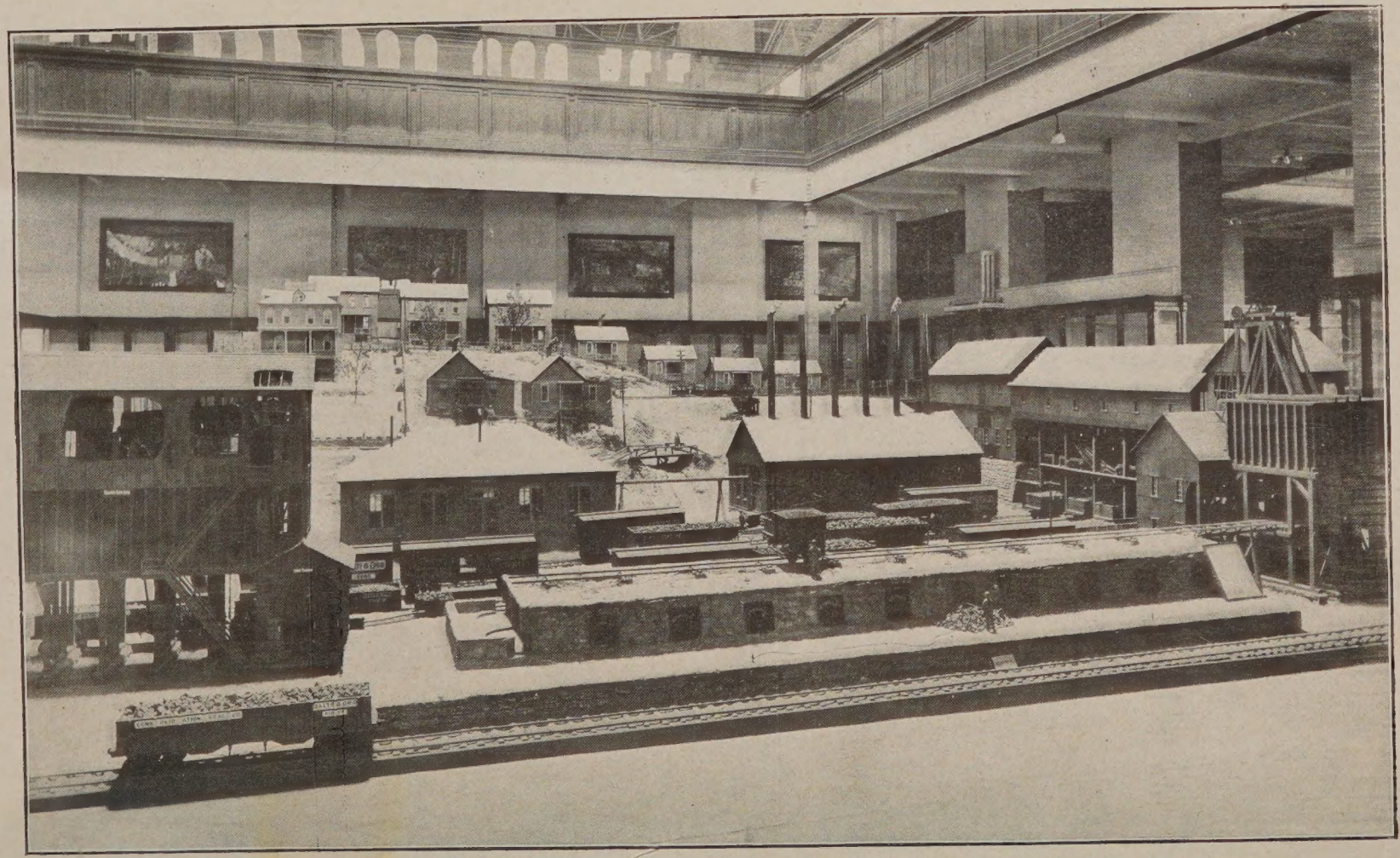

VIEW OF COAL PRODUCTS, EXHIBITION HALL, UNITED STATES NATIONAL MUSEUM.

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THE MINERAL INDUSTRIES OF THE UNITED STATES

COAL PRODUCTS: AN OBJECT LESSON IN RESOURCE ADMINISTRATION

BY

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BULLETIN OF THE UNITED STATES NATIONAL MUSEUM.

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COAL PRODUCTS: AN OBJECT LESSON IN RESOURCE ADMINISTRATION.[1]

By CHESTER G. GILBERT,
Curator of Mineral Technology, United States National Museum.

Civilization's foremost function is the nourishment of human life and manufacture is the expression of man's effort toward providing the broadened means toward this end. The mere vision of smoke and grime and the grinding away of human lives in the purely selfish search for material profit is superficial. The deeper significance of manufacturing industry is that of providing the essentials for multiplying humanity, and to make the most of potentialities toward manufacture is not merely to set up a goal of self-aggrandizement; it is one of the profoundest obligations of a people in behalf of posterity, even in behalf of the world at large to-day. If this is true of industrial enterprise as a whole in its relationship to national responsibilities, it applies with altogether distinctive emphasis to the activities involving a country's coal resources. Mankind is dependent upon coal in the home; but more than that, coal contributes the muscle and sinew for industry whereby practically every other material necessity of life is rendered available to use; and even in addition to being the fuel dependency of the age, it is capable of being made to yield an almost indefinite number of other necessities without sacrifice from the fuel element.

Coal in short is the nucleus around which the material growth of civilization builds. Thus an explanation opens up to the fact that Europe is the center of present-day civilization. Coming into existence there, the civilization of the present era found, when the need developed, ready at hand in the form of adequate coal resources, the means toward the evolution of its destiny. Thus the series of cubes shown on plate 3, sized proportionately to the coal resources of the various continents, is highly suggestive with reference to the future indicated for the maturing aspects of this civilization in its spread toward world inclusiveness. One sees a vast industrial rehabilitation in Asia, while the responsibilities of South America and Africa are indicated as lying essentially in the provision of raw

[1] Interpretation of the Coal Products Exhibit in the U. S. National Museum.

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materials, and Europe would presumably become more and more the source for refinement of industrial procedure and the clearing house of world trade.

For additional comparison, a cube showing the relative importance of the coal resources of the United States is given place in the series. Noting the share of the world's supply thus represented, a conception of the industrial potentialities of this country opens up, reaching beyond the grasp of the imagination. Yet entrusted with a great share of what the whole world has to rely upon for material support in the encompassing progress of civilization, the yield from this vast heritage has not been made to respond adequately even to current purely domestic needs. True, it is energizing a vast industrial development, and thus far at least it has met the fuel requirements of the American home; but these are only two of its three functions, and as a matter of fact their ends are attained through the actual normal employment of only about two-thirds of the mass representing coal. The other third embodies a veritable treasure house of products catering to needs of civilized man, and the spectacle of the United States, with its dominating bulk of potentiality, helplessly pleading with European countries to render coal-product assistance despite the overwhelming nature of their own troubles, is fresh in the minds of all. It is not a spectacle to be proud of, but it is one well worth contemplating in the light of an object lesson.

Growing out of the composition inherent in the nature of coal, the subject may be approached to best advantage along the lines of origin. Taking the averages of composition representative of each coal type, it will be found that these are capable of an arrangement wherein the various familiar classes of coal such as lignite and anthracite appear as so many stages in a process of chemical evolution. Such an arrangement is represented in graphic form on plate 1 and points significantly to vegetal accumulations as being the source of coal. The further confirmation of the same, the actual fossil outlines of vegetal remains found in diminishing fullness of preservation from peat upward through the successive stages to anthracite, are conclusive. In fact, the fossil forms of vegetation are sufficient to enable the imagination to supply what is lacking and depict original conditions with reasonable assurance of accuracy. This has been done by Unger, among others, and his restoration is reproduced on plate 2.

It is to be observed to-day that the thickness of the vegetable mold blanket bears a direct relationship to the degree of moistness. This is partly owing to the increased luxuriance of growth under such conditions and partly due to the protective influence the water exercises against the oxidizing attack of the air; and the combined

tendency of both together is toward providing an increased rate of accumulation over that of decomposition. Where conditions have been particularly favorable to the maintenance of the relationship just mentioned, peat bogs are the result. Peat accumulations as much as 40 feet in thickness exist, and while there is a vast gap between even a 40-foot peat bog and a 40-foot coal bed when it would require the carbon of a 40-foot thickness of peat to yield a 1-foot thickness of coal, still, as indicated above, a complete chain of connecting links in material fact exists, and the only leeway for divergence in theory lies in modifying the details of condition with a view to accounting best for the enormous lateral extent and thickness of the accumulation.

Entering into this discussion only sufficiently to derive an explanation for the present occurrence of coal as a formation between the more conventional rock types of shale and sandstone, down in the earth's solid crust instead of on the surface, as its origin would suggest, the most satisfactory inference is that of a vast marine swamp area gradually sinking. This does not require any stretch of the imagination, inasmuch as progressive changes of this order characterize the relation between land and sea elevation in general to-day.[1]

With the balancing tendencies of a swamp area slowly settling and of organic accumulations slowly building, a shallow swampy character of inundation might well be protracted indefinitely, allowing for a correspondingly indefinite thickness of peat-like accumulation. With the rate of submergence at length gradually gaining the upper hand, vegetation would slowly be drowned out, and the area absorbed into sea bottom by the encroaching water. Then in the largely land-locked sea area resulting, the relatively calm waters would receive the silt from inflowing streams and let it settle quietly to the bottom, thus allowing for a continuance of the process of accumulation, but causing a change from organic carbonaceous material to that of an inorganic clayey nature. Realizing the relative boundlessness of geologic time, proceedings in this stage in the evolutionary process would be capable of any degree of extension, resulting in the burial of the organic deposit under an indefinite thickness of sediment whose character might change with changing conditions of submergence from essentially clayey to essentially sandy, or essentially calcareous matters, yielding almost any thick-

[1] For instance, to the northward of the general vicinity of New York the land of the coast line is subsiding while to the southward the reverse is true. Incidentally it is the advancing water boundary with its encroachment upon the land surface in the one case, and the receding water boundary with its consequent exposure of beach area in the other, which accounts for the rugged New England coast and a flat sandy South Atlantic coast.

ness of layers. Ultimately, however, the proceeding enters into another stage in the form of a reversal to a rising instead of a subsiding movement. This in due season means the final reappearance of the area as dry land with the one-time swamp accumulation of organic matter buried deep down in the earth. The pressure of the vast weight of materials above, coupled with the various other geologic agencies needless to recount here, will have compressed and condensed the peaty aggregate to coal and welded the sediments into beds of shale, sandstone, and limestone, as exemplified in plate 5.

With the emergence of the region as dry land, the process of coal evolution enters into its closing stages. Erosion or the gradual wearing down of all land areas provides the reverse aspect of accretion or the building up of sea-bottom areas; and the rate of erosion is commensurate with the abruptness of elevation. It is not to be expected that the dynamic forces behind the upward movement would necessarily produce an even uplift; rather it is to be expected that zones of relative weakness would develop and that the uplift would be uneven. Erosion then would proceed unevenly over the area; and in the course of geologic time might here and there succeed in wearing completely through the overlying rock mantle, even cutting through the coal and far into the underlying rock. The result would be the outcrop of a coal bed, and from that point forward the material history of coal, till then involving time in periods defying any attempt at reference to human standards of measurement, is ready to merge into the history of man.

From the foregoing brief sketch of the history of coal evolution, it will appear by way of introduction to what follows that coal is a development from organic accumulations, effected presumably in vast marine swamp areas, and the various classes of coal represent so many different stages in the transition from vegetal to stony condition of occurrence; that the transition is induced primarily by the physical element of pressure with its accompaniment of heat; and that accordingly the anthracite stage of the evolution does not necessarily imply a formation of greater age, but rather marks a more extreme phase of metamorphism whether from duration or from intensity. The natural tendency from external pressure is toward condensation, and that is precisely the nature of the evolutionary development wrought by the dynamic forces of pressure and heat in coal. Physically it takes the direction of a progressive condensation toward the stony extreme of anthracite; and chemically, as may be observed in the chart, there is a corresponding tendency in the progressive elimination of the lighter, gasifiable, or volatile ingredients. These are the conditions native to the occurrence of coal which furnish the groundwork for the structure of industrial usage.

Within the immediate range of vision of a great share of the public, anthracite offers an even more familiar sight than the bituminous grades of coal; and, as a matter of fact, quite apart from the more intimate nature of its relationship to household economy, it furnishes nearly a fifth of the total for consumption. In the face of this ratio in consumption, the extent of the country's resources in the two directions provides a contrast replete with significance in connection with the domestic fuel situation. From the evolutionary sketch it comes as a natural inference that the occurrences of anthracite are restricted, but the degree of limitation affecting its occurrence is not generally appreciated. A map of the United States showing the areal distribution of the two is reproduced on plate 4, and a graphic expression of the comparison in terms of bulk is included amongst others on plate 3. A glance at these is sufficient for the conclusion that the responsibility imposed on anthracite coal is out of all proportion to the resources at hand.

The present purpose is not concerned in the moral issues involved between anthracite production and consumption. It is enough that there exists the national predicament of a household fuel dependency so restricted as to be open to control by the merest few operators acting in concert. Furthermore, whatever the call for the exercise of a corrective influence over the conduct of the operations, fundamentally the predicament, with all of its unfortunate tendencies, arises as the normal outgrowth from an ever-increasing demand upon resources of an altogether disproportionately limited order. Accordingly the mere heaping of condemnation upon what, despite any incidental shortcomings, constitutes one of the most efficient types of producing organization in American industry is as futile as it is superficial. Substantial relief is to be found only in some form of fundamental revision opening up enlarged domestic fuel availabilities.

Only the unsubstantiated imagination can range beyond the use of coal in one guise or another as a fuel basis, so for direct practical results the country must turn to its vast bituminous coal resources. The prospect opening up directly in the extended use of raw bituminous coal is not a refreshing one, however, for aside from the discomfort it means to the individual user, it brings a vision of disaster impending over the work of civic betterment. Smoke, it is true, merely implies incomplete combustion, or, in other words, the escape of distilling volatile matters before they may be consumed, and insuring complete combustion would in itself obviate the smoke-producing objection to raw bituminous coal; but complete smokeless combustion as a result from the general use of bituminous coal in the home at least may safely be regarded as an unattainable ideal. Smokeless combustion as a generally applicable reality can result

only from the general use of a smokeless fuel. With the passing of anthracite, the great natural smokeless fuel, into the realm of life's luxuries, hope must look toward the development of a new smokeless fuel dependency artificially from bituminous coal. The relationship between the two types as brought out in the historical sketch lends plausibility to the idea; in fact, makes it appear logically to be expected, for if nature evolved smokeless anthracite from bituminous coal it is natural that man should seek in the same direction for its artificial equivalent. As a matter of fact he has not needed the inspiration to be found in the example furnished by nature. The evolution of a smokeless carbonized fuel is the first stage in the burning of bituminous coal.

Exposed to the temperature of boiling water, some of the volatile ingredients in the make-up of bituminous coal begin to break loose and escape as gas, and as the temperature increases the process becomes more active, giving rise to flame or smoke. After more or less protracted exposure to red heat all of the volatile ingredients are freed, leaving a solid residue amounting to approximately two-thirds of the original coal weight, which then burns quietly without flame or smoke. Extinguishing the fire as soon as the preliminary distillation stage is past instead of allowing it to continue through the smokeless stage of combustion, the residue will have a chemical composition analogous to that of anthracite and from the chart, on plate 1, the chemical procedure itself will be seen to be similar to that involved in the natural evolution of coal. Physically, however, there is an important difference in the two, the importance of which will be dwelt upon later. In nature's laboratory the agencies of pressure and time duration were expended with a lavishness beyond all hope of human approximation, resulting in the dense stony characteristics of anthracite, whereas in the artificial product the escaping gas in the pasty body of the distilling coal develops cellular structure exactly comparable to the familiar instance of bread making.

This coherent spongy mass representing the nonvolatile residue left over from the distillation of the volatile ingredients in bituminous coal is known as coke. Coke then is the artificial expression for the results attained by nature in the form of anthracite, but with important differences arising from the fact that whereas the latter is the outcome from a geologic vastness of time and pressure operating in conjunction with heat, the former comes as the direct response to heat alone. Around coke centers not only the opportunity for relieving the domestic fuel situation, but every manner of coal-product supply as well, so a special degree of interest attaches to its character and adaptability, the more especially since coke is not altogether unfamiliar as a household commodity and has been to a considerable degree misjudged as to its possibilities of value.

Weight for weight coke offers about twice the bulk of coal, and the result is a corresponding difference in fuel properties, as anyone who has used coke has experienced. Speed or energy of combustion is of course proportionate to the area exposed to the attack of fire, and, conversely, susceptibility to chilling below combustion temperature, or to "going out," varies in like manner. Thus the greater bulk of coke with its aggregate of cell walls means a correspondingly increased surface exposure to attack in burning, and under adequate conditions a correspondingly more intense fire. Thus, too, on the other hand, it means a correspondingly greater liability to become chilled and extinguished if neglected. In short, lightness of substance giving a flighty tendency toward extremes of behavior are the outstanding characteristics of coke as a fuel.

Where an extreme of clean heat is the aim, coke is the best practicable solid fuel obtainable, and hence its adaption as the standard for metallurgical use. But susceptibility to control is one of the first requisites for a satisfactory general-purpose fuel, and accordingly coke has not found favor in that direction. In view of the prejudice existing against it, several facts deserve consideration. In the first place the whole development of coke quality has been in the direction of obtaining the maximum of intensity in combustion under the designation of metallurgical coke, a specialization quite at variance with the requirements of a general use fuel. Again, the use of any particular fuel requires appropriate facilities and understanding, and to condemn coke on the basis of its behavior under the treatment evolved for coal is comparable to judging the merits of anthracite on the basis of its behavior in a wood stove. Finally, the question which is slowly and certainly gaining in pressure, is not that of providing a fuel competitive with anthracite on equal terms, but one capable of practical service in the capacity of a commodity as against anthracite in the growing capacity of a luxury. A tendency away from anthracite is certain to set in, and the only room for choice lies between coke and raw bituminous coal. Relative economies are bound to be an important factor, if not the deciding one, in the choice. Right here the domestic fuel situation in the United States connects up with the coal product one in a manner which renders the two interdependent in their requirements; for if the general purpose use of coke fuel is to be economically practicable, it can be rendered so only through the support of values derived from that other third of bituminous coal mass removed as volatile matters in the course of carbonization, and, conversely, an extensive preparation of coal products necessitates an advantageous coke market. The answer to the whole question is to be found in the value of the distillates derivable. If this latter can be made to overbalance the cost of preparation, the surplus constitutes just so much potentiality for economic advantage in favor of coke for the householder.

The volatile third of bituminous coal as it distills off on heating consists essentially of the familiar household-commodity coal gas, commonly supplied to municipalities. Thus, quantitatively, there are two major products from coal, and as a matter of fact the coal-product industries of to-day are a development from two distinct industrial sources, the one producing coke for metallurgical use, the other providing a municipal gas supply. A large measure of this original distinctness has persisted even to the present day in America, despite the remarkable fact that the only essential difference is that the product in the one case constitutes to a great extent the waste or at least the inefficiency in the other, and the reverse. The fundamental aspects of each separately, followed by the combination of the two into a mutually complementary whole, provides the best approach to the present coal-product industry whereby, as has been indicated, the opportunity for a smokeless fuel supplemental to the waning anthracite resources is to stand or fall.

The relationship which coke bears to coal parallels that of charcoal to wood and the manufacturing procedure has developed along similar lines. If bituminous coal is ignited and allowed to burn with sufficiently limited air supply, the burning will be confined to the escaping volatile portion; and, in turn, the heat of this gaseous combustion will maintain a temperature in the coal mass sufficient to cause complete distillation of the volatile ingredients, yielding coke as the product. The earliest application of this principle to coke manufacture was in the form of open-heap roasting, illustrated in plate 6, but this procedure quickly gave way to a practice of burning within an oven so constructed that the incoming air, instead of passing through the coal bed, meets and mingles with the distilling gas in the dome-shaped upper part of the oven, where combustion is accordingly confined. The inclosed oven with its dome-shaped roof is known as the beehive coke oven. In it the only product saved is coke, the volatile matters providing the fuel for their own distillation. If instead of some form of direct smothered combustion such as that provided in the beehive oven, however, the coal be heated in a sealed inclosure—a retort, in other words—the distillation will proceed as in the open, and the entrapped gases and vapors may be piped off from the retort to suitable receptacles for further treatment. This is the principle upon which municipal gas works supplying coal gas operate. Just as the battery of beehive coke ovens is to-day's expression of the solid fuel line of coal-product development as a distinct issue, municipal gas manufacture, the other distinct issue, finds its typical expression in the arrangement of retorts illustrated under the name of gas bench on plate 8.

Contrasting the operations of the two, the beehive oven is open to the air whereas the bench retort is sealed off from air; the bee-

hive oven is heated by the combustion of its oven gases within the inclosure while the bench retort is heated from an external source commonly derived from its own coke of earlier yield; and lastly the production of first-quality coke is the one and only aim of the beehive operations whereas the bench retort includes the production of first-quality gas along with the incidental saving of a more or less nondescript coke and possible eventualities in all of the other coal distillation products:[1]

In the case of the gas bench, the coke yield is of a quality unsuited to metallurgical use; in the beehive oven on the other hand only a small fraction of the gas generated is necessary under adequate conditions to maintain the temperature necessary to distillation. Accordingly two industries exactly complementary in fundamental character, were obliged to travel their own courses of separate wastefulness side by side for upward of half a century, pending the evolution of a system combining the coke advantages of the beehive oven with the distillate saving of the retort type. The problem offered manifold complications in the form of operative efficiency, and despite the heralding of various attempted solutions, it was not until the decade beginning in 1880 that installations fully adequate to the test of practice were established. Credit for the accomplishment belongs unqualifiedly to German enterprise. Once established, advance was rapid, and the coming of the present century found an extensive coal by-product industry centered in Germany and the beehive oven battery supplanted throughout continental Europe by the so-called by-product coke plant.

The aim in the by-product coke plant is, as its name implies, the generation of a coke in conformance with the standards set by the beehive oven, coupled with the saving of volatile matters effected in connection with the gas retort. In principle the modern procedure is identical with that of the gas bench, the essential difference originating in the practice of employing retorts of many times the capacity of the gas retort with a proportionate rearrangement and elaboration of plant construction throughout. The retort ovens

[1] The beginning in the history of the two developments may be of interest in passing. Back as far as 1817 the Pittsburgh Chamber of Commerce, noting the rapidity with which the wood supplies available for the preparation of charcoal fuel, the accepted metallurgical fuel at that time, were becoming depleted, commissioned a representative to investigate a rumored usage in England of a product of similar derivation to charcoal only from bituminous coal instead of from wood. The rumor was substantiated and presently the product known as coke began to find favor among American metallurgists. From these beginnings the metallurgical use of coke has grown steadily to the present vast proportions involving an average of over a million tons of coal a week in its preparation. The uses of coal gas began further back in 1792 when William Murdock illuminated his home in Redruth, England, with the distillate from coal in a retort which he devised for the purpose.

are long narrow rectangular gas heated inclosures, ranged side by side in batteries, to allow for mechanical charging and discharging and similarly the treatment accorded the various by-product recovering steps is marked by a maximum of saving elaboration. The general nature of the procedure will be found illustrated and explained on plate 9.

Tracing the course of the operations as depicted it will be observed that in addition to coke as the major product, the output includes gas, tar, and ammonia, the latter either as such or in the form of the sulphate. By the introduction of additional installations, omitted in the interests of simplicity, the segregated recoveries may and commonly are extended to include benzol and perhaps one or two other derivatives of lesser import. These, together with a 12 to 15 per cent increase in the coke recovery, constitute the direct results accruing from the modern type of operations as contrasted with the crude procedure represented in the beehive oven. More definitely expressed, the contrast means a saving of around 200 pounds of coke, about 5,000 cubic feet of gas, some 15 gallons of tar, and the ammonia in 20 pounds of ammonium sulphate along with 2 gallons of benzol for every ton of coal coked.

The operations represented in the illustration with the products given comprise the immediate field of by-product carbonization as employed in direct opposition to the beehive type of procedure and to the operations growing out of the gas retort bench. The development of the principle has not stopped here, however, but has been extended to fulfill a far greater, more comprehensive function with reference to human welfare through what is termed the coal-product industry and its consequent coal products or coal-tar derivatives. The diagram prepared by the United States National Museum's valued contributor, Mr. C. G. Atwater, and reproduced herewith through the courtesy of the Barrett Co., of New York, outlines better than words the whole potential significance involved.

The diagram is suggestive in three directions of importance in the present connection. First of all it brings out the relationship of by-product coking to the coal-product industry as a whole; namely, that of being only a preliminary though an indispensable preliminary to the whole. Next it provides a definite basis for a comprehensive imaginative grasp of what the industry in its fullness of development has been made to contribute toward furthering the ends of progress. Finally, it leads to the all-important conception of a single great intricate evolutionary creation, the various specific industrial members of which can function only as they operate in coordination with the rest. These three are the essentials fundamental to an understanding of the coal-product situation as it has come to exist in the United States to-day.

Of the foregoing three considerations, the first named, that of the capacity in which by-product carbonization appears, is a connection too fully evident in the diagram itself to call for further comment. With reference to the second, the importance of the products to society, pages would be involved in any attempt to trace with anything like finality the influence of the various products specifically. The significance involved in the situation as a whole, however, is capable of expression in terms of a simple comparison. On the one side stands the chimney stack with its all too familiar contribution; on the other an elaboration of industry offering instead a veritable storehouse of treasure to the use of society; a storehouse affording essentials in agriculture, pharmacy, photography, textiles, disinfection, explosives, refrigeration, painting, paving, waterproofing, wood preservation, and an ever-widening circle of more specific requirements touching every aspect of human life. The magnitude of the contrast is precisely the measure of coal-product potentiality.

Another and more far-reaching significance attaches to the comparison, a significance in which the fundamental reason for the inadequacy of the country's coal-product developments may be recognized. The one, a direct hand-to-mouth economic procedure, is the attribute of a cruder stage of social evolution; the other, an elaborately involved adaptation, can come only as the outgrowth of refinement. The resources at hand awaiting employment in the past have exceeded in both magnitude and multiplicity the facilities available for their adequate utilization. The consequence has been toward preserving the cruder economic tendencies with expression in the form of dissociated opportunist industrial activities rather than toward the evolution of any true economic organism of coordinated industrial parts. Coal-product manufacture, with its elaboration of complex interrelationships calling for coordination of development along scores of directions at once highly specialized and widely diversified, represents the most advanced order of industrial evolution thus far attained. Amid the crudity characterizing the American economic system in the past such an establishment would have been as incongruous and as incapable of growth as a movement toward internationalism in the environment of the Dark Ages.

The dawning of economic consciousness in the progress of a civilization is marked by evidences of a hoarding instinct. So in the belated evolution of the scheme of industrial life in America the past decade has manifested in the crude conceptions of conservation sporadic evidences of a similar stage with reference to the application of industry to the natural material resources of the country. Crude though these conceptions have been, to ridicule them in the light of existent conditions means failure to recognize in them a step in ad-

vance toward a riper consciousness of national responsibilities in that conservation which, looking toward adequacy of employment rather than improvidence on the one hand or static hoarding on the other, seeks consistently to bring about the employment of the various means toward that end as they emerge from the channels of research. Vaguely an awakening consciousness in public opinion is coming to a discerning conception of some such national economics, but as in the conspicuous instance of the nitrogen situation, the response thus far has been spasmodic, uncomprehending, and expressed through media inadequately developed.

With the resources of a country constituting the opportunity opening to its people, it follows that enhancement in the value of a natural resource is bound to represent not merely increased dividends for a favored few, but, in the last analysis, an actual corresponding increment to genuine unrestricted opportunity. In this connection, with coal the country's greatest material heritage, the growth in its potentiality as yet ignored, furnishes a most impressive object lesson in resource administration. Twenty-five years ago the practicable potentiality recognized for the use of bituminous coal was approximately:

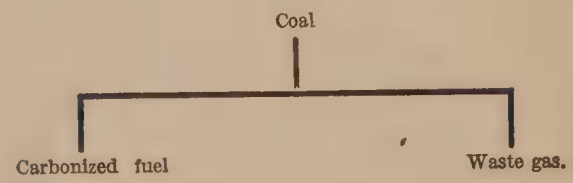

Plate 10 gives the current expression of precisely the same situation. The two speak for themselves, offering a contrast of growth which challenges duplication elsewhere in the whole progress of civilization for a like period of time. Important enough in its specific fact of application to the country's dominant material resource, the full significance of the contrast opens out in proportion as it is seen to apply throughout the whole range of chemically conducted industries, whereby the raw resources of a country are being consumed in the saving or wasting of the multitudinous products essential to the ever-widening requirements of independent national existence.

There is a popular form of misconception which holds the impression that the source of a given commodity is immaterial so long as the needs with reference to that particular article by itself are met advantageously. Fifty years ago such an impression represented a reasonably accurate interpretation of existing conditions, but of recent years a totally different situation has been developing. The change has been brought about through the constantly widening circle of acquaintanceship being made by chemistry amongst the ingredients entering into material compositions, and has manifested

itself in the branching out of the opportunities open to industrial procedure. Twenty-five years ago a raw resource commonly lent itself to characterization as a commodity plus impurities; but to-day it offers instead a composite of ingredients, some recoverable to advantage under existing conditions, others not open to profitable recovery, but all possessing definite individual properties, open to employment in meeting the widening needs of civilized man. The term "waste" employed in designating the discards from industrial procedure is more than a name; it is a highly significant characterization. A very large numerical percentage, including even the more important commodities in current use, are of by-way derivation; and the rate at which their numbers increase marks the industrial progress of a people, for therein lie the greatest of all potentialities, not only for practicable resource conservation but for all-round economic efficiency as well.

The results of this broader conception find their expression in the extended application of methods for the recovery of these so-called by-products as soon as the requisite demand is created. In some instances a given by-product is recoverable by itself independently of its associates, but, in the nature of things, it more frequently happens that a whole series of by-products are linked together and they must find place for development as a group or remain as a group amongst the industrial outcasts, discarded under the classification of waste. Each of these groups, moreover, is inseparably connected with other similar ones, both providing ingredients essential to the others and dependent in turn upon the ingredients the others provide. Thus, from offering so many simple, direct, individually distinct lines of procedure, the conversion of a country's raw resources has come to constitute a vast industrial labyrinth of ramifying, interconnecting, and interdependent chemical procedures, the whole constituting the industrial fabric of the country, and, incidentally, the basis for what the individual has of material comfort and prosperity. The channels do not follow chance directions at random; in so far as they are opened up, they follow courses mapped far in advance by chemical research. Just in proportion as the opening up and maintenance of these channels of interdependence is provided for in accordance with the advances of chemical research, efficiency, conservation, and stability are assured to industrial development; and, conversely, just in the proportion that the necessary provisions are not looked to consistently as an obligation of fundamental importance to national existence, inefficiency, wastefulness, instability, and subservience are bound to remain characteristics in the industrial life of a country. America offers no exception.

Public opinion has of late been disposed to manifest a special degree of interest in speculating on the stability of the current indus-

trial expansion within the United States, once world conditions have again been restored to normal. With industrial life as with other forms, static condition is impossible short of death. The question is not one of whether or not American industrial activity will be able to hold what it has, but that of whether or not it will continue to expand or presently begin to lapse. The expanding coal-product industry is the one most frequently mentioned in this connection. The answer is that a coal-product industry is not the outcome of vacillating chance.

The chance of current events has given rise to a special opportunity, a most extraordinarily auspicious one, in fact, but unless or until the employment of scientific guidance in the commercial following of the trails blazed by scientific exploration becomes an ingrained principle in the directorship of industry, both governmentally and privately, American industrial progress is bound to go astray and fail through inefficiency when exposed once more to the test of competition against the developments from consistent scientific guidance abroad, excepting where, as in the past, natural advantages of resource have been sufficiently great to overcome the handicap of miscontrol. Coal-product manufacture, despite the advantage of enormous resources, has not been able to make place for itself in this latter category.

The present opportunity is a passing one and one which, it is to be hoped, despite the advantages afforded, will not recur soon. To impart stability to the expansion it has given rise to, public opinion must recognize that what in the last analysis is best for the industries engaged in converting the resources of the country into usable form, is also in the last analysis best for the individual, and then act accordingly. Once that realization is fully established, and no clearer illustration of its truth could be desired than that afforded by the coal-product situation, the nature of the resultant action is foreordained. It will lie in the direction of scientific control of chemical industries. Lack of it has been the stumblingblock for American enterprise in the past, and continuance along the old lines of procedure implies a negative answer to the popular question as to whether expansion of the chemical industries in general, and the coal product one in particular, will continue toward an adequate realization of their enormous potentiality following the world's return to normal conditions. This means the relapse to a state of industrial instability, inefficiency, wastefulness, and subservience, a calamatous prospect when the magnitude of the opportunity at hand is considered. Hope looks toward the establishment of a definite economic policy giving the encouragement of an appreciative and understanding public support in the coordination of industrial development.

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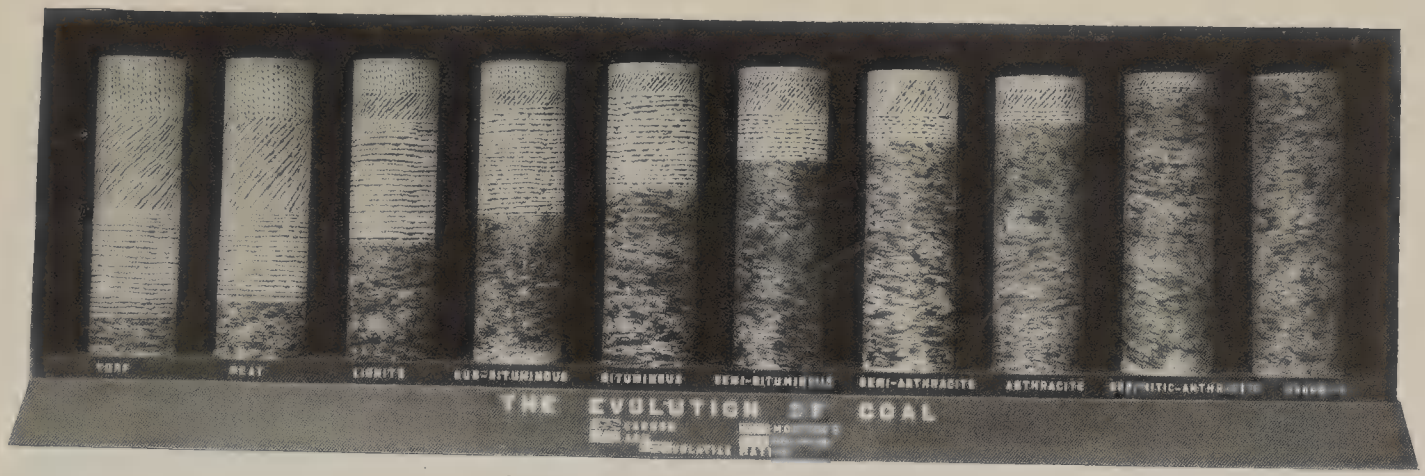
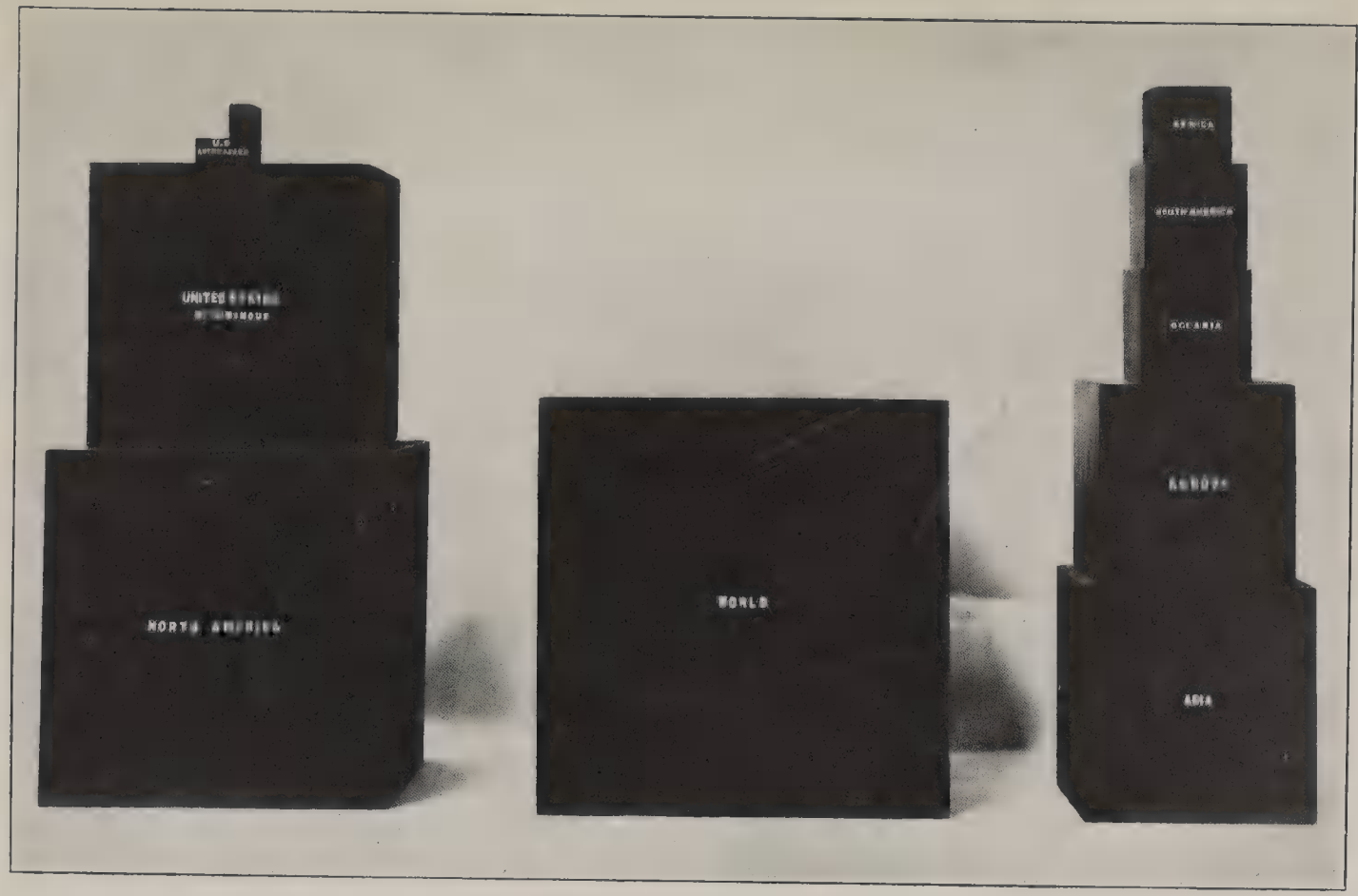


ORIGIN AND DEVELOPMENT OF COAL.

This exhibit shows the successive chemical stages in the evolution of coal. The striking qualities of the original are lost in the reproduction through the use of designs in the place of realistic coloring, but the effect is retained sufficiently to indicate the nature of the sequence and the directness with which it leads back to an origin in vegetal accumulations. The evolutionary process is seen to take the form of increasing density through the progressive expulsion of volatilizable matters in the course of geologic time. This inference is substantiated beyond reasonable question by the actual presence of organic remains in coal beds.

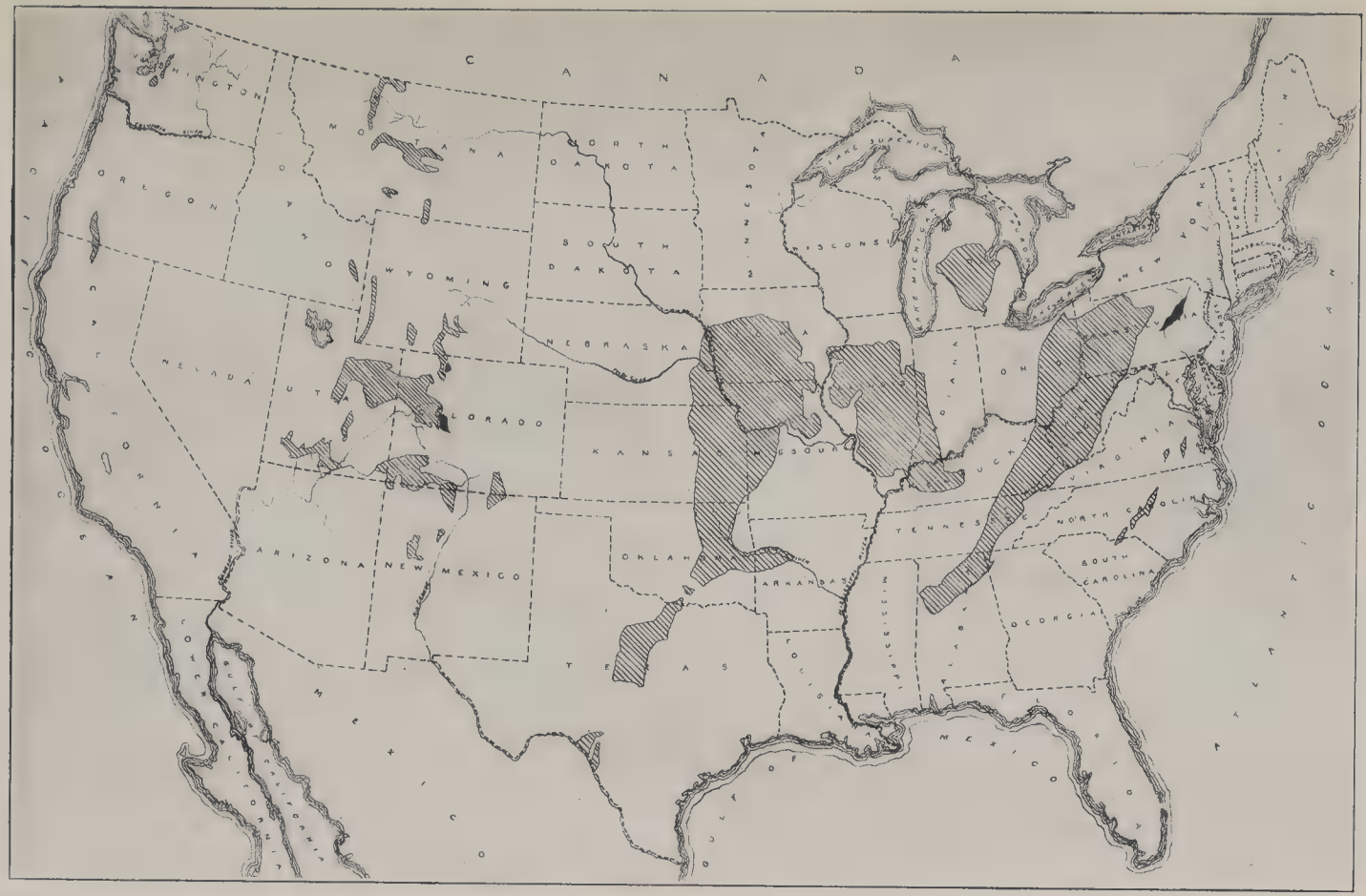
COAL PERIOD LANDSCAPE.

The first stage in the evolution of a coal bed.



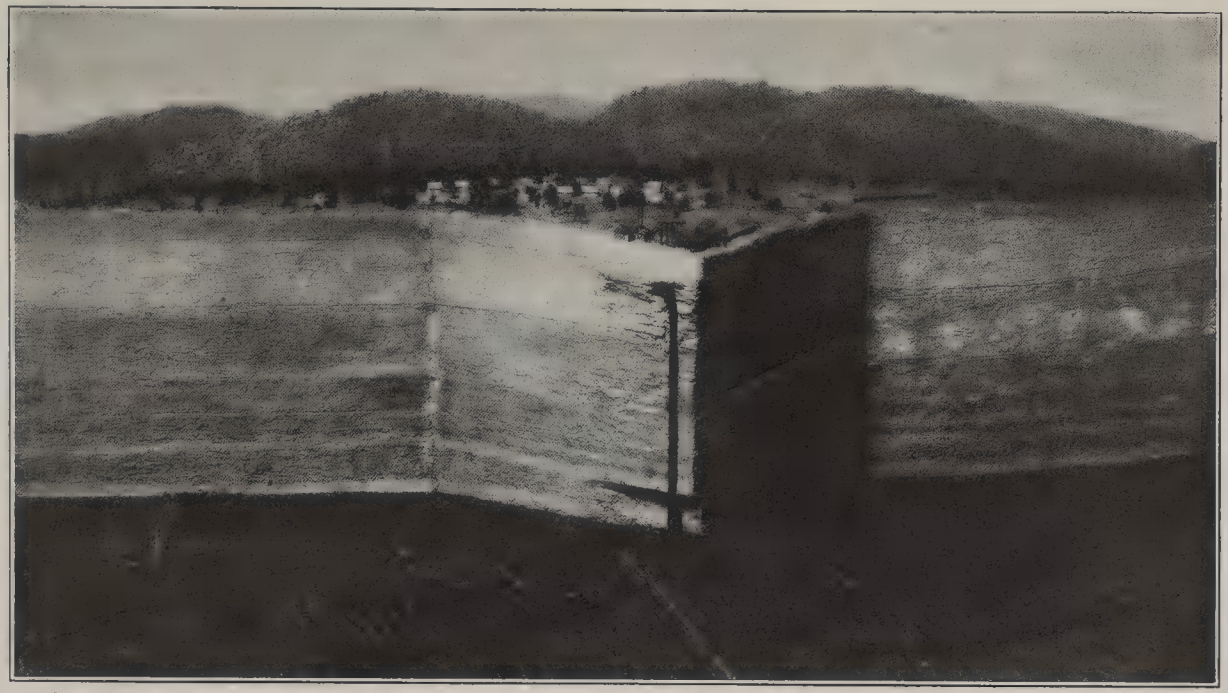
CONTINENTAL DISTRIBUTION OF COAL.

This exhibit represents how the world's coal supply is apportioned amongst the different continents; also the portion contained in the United States. What is missing from the anthracite cube represents the approximate consumption to date.



DISTRIBUTION OF COAL IN UNITED STATES.

Map showing the known distribution of anthracite (black areas) and of bituminous coal (hatched areas). The contrast afforded is impressive in view of the importance now attached to the former.

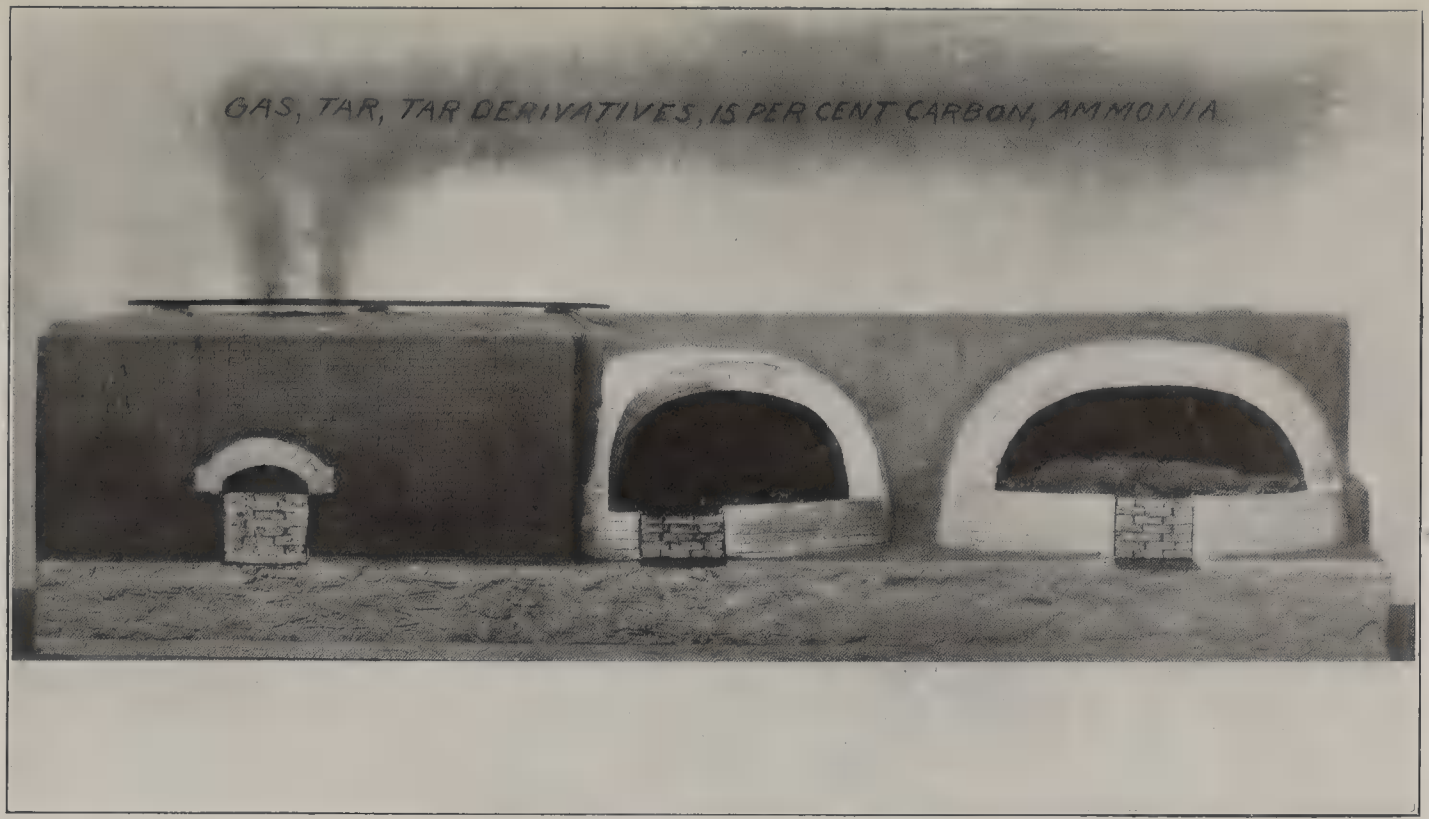


OCCURRENCE AND MINING OF COAL.

The rock layers or strata above are shown cut through vertically and removed, leaving a flat extent of coal exposed. Tipple, shaft, and layout of haulageways and mining operations are to be seen in their proper relationship. To the left and extreme right are operations in progress in solid coal, but near the shaft the coal has been largely removed excepting for the ribs left to support the overlying rock. The thickness of the coal bed is represented in the height of these ribs, and its conformity of relationship with the layers or strata of commoner sedimentary rock associated with it is apparent in the section through the rock above. From a model donated by the Western Coal and Mining Co. of a mine at Jenny Lind, Arkansas, and in the coal products exhibit of the United States National Museum.

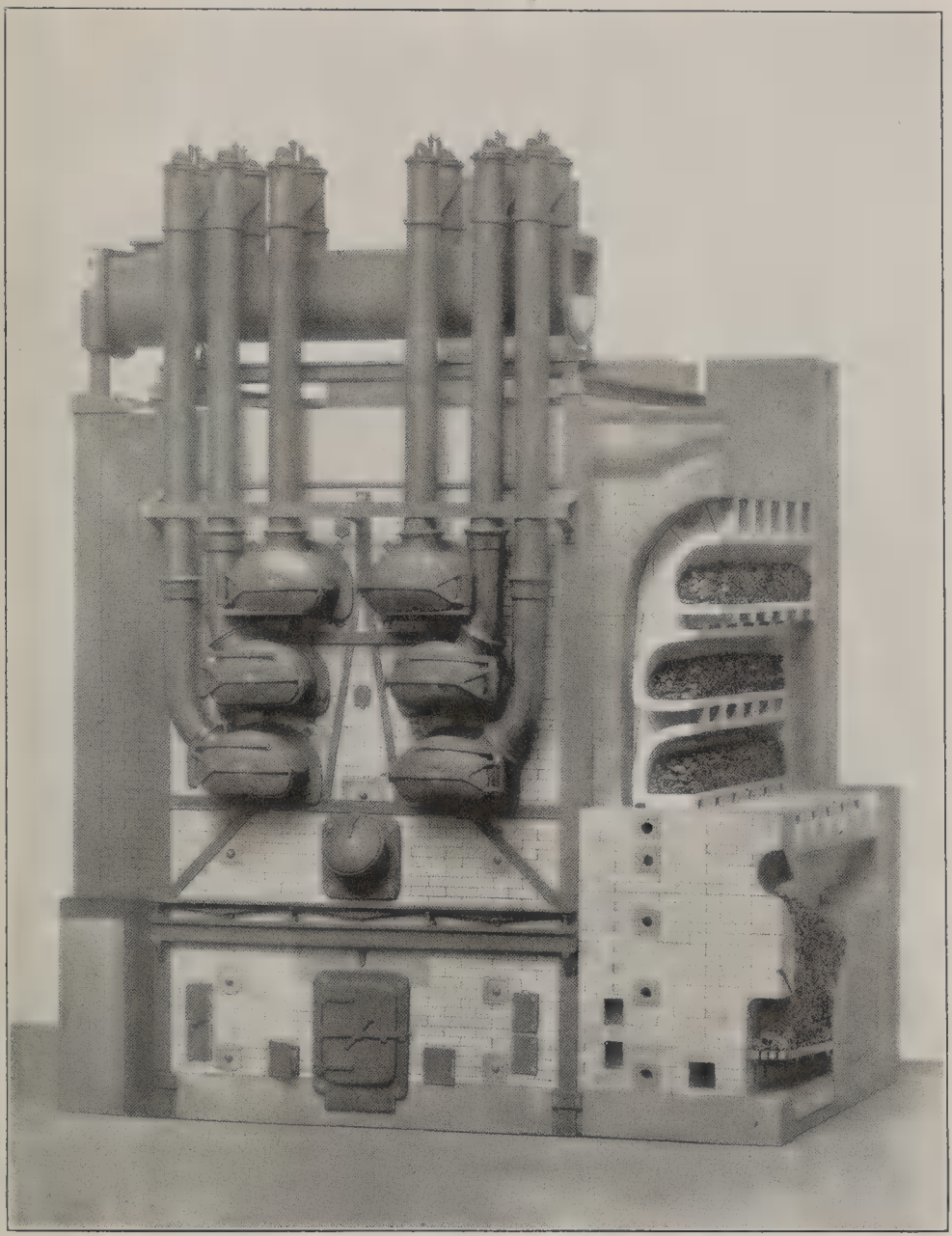
BENNINGTON COKE PILE.

Earliest American method in the coking of coal, supplanted by the inclosed oven of the beehive type. The procedure started with an open heap of coal provided with a system of draught as shown in the portion removed. The fire was kindled under the vertical flues and combustion was kept smothered by banking with powdered coal. From a model in the coal products exhibit of the United States National Museum.



BEEHIVE COKE OVEN.

Oven coking typified in the beehive oven. An oven is charged through the top with 5 tons of coal, filling it to the height of the brickwork in the front opening, and the charge gradually brought to distillation temperature by the heat communicated from adjoining ovens. The escaping gases ignite and, burning in the dome of the oven, increase the heat, thus continuing the process of contributing heat as that in the adjoining ovens diminishes. The entrance for air, being above the coal bed, combustion is kept confined largely to the volatile matters as they distil in the dome. After 48 or 72 hours the residual coke is quenched with water, withdrawn, and a fresh charge of coal introduced. Relative simplicity of construction and operation, coupled with excellence of product, are its advantages; and it is only slowly giving place to modern developments. Its disadvantages, on the other hand, as indicated in the illustration are intolerable to enlightened society. From a model in the United States National Museum.



GAS RETORT BENCH.

A complete bench of six retorts and adjoining one sectioned showing operative features. Coal is charged into the retorts, about 200 pounds to each retort, and the doors closed tightly. When heated from the coke fire below, the volatile ingredients break away, and are carried off for further dissociation into gas, tar, and ammonia. The residual coke is then withdrawn for use primarily in maintaining the temperature of the retorts and secondarily as a by-product. The gas bench is thus of the by-product recovering order so far as the volatile portion of the coal treated is concerned, but the quality of coke is inferior; so in advantages and disadvantages alike it presents the exact reverse of the beehive coking procedure. From a model in the United States National Museum.

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